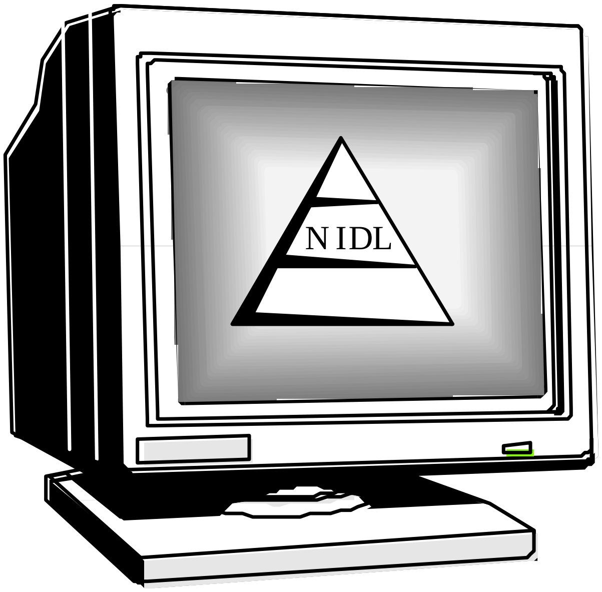

NIDL certifies the 21 inch Cornerstone p1700 color monitor as being suitable for IEC workstations. NIDL rates this color monitor “A” in monoscopic and “B” in the stereoscopic mode for the Image Analyst and Cartographer applications. The Cornerstone p1700 is an excellent color monitor. It meets the stringent IEC 120 Hz (60 Hz per eye) stereo requirement. It can display up to 2048 x 1536 pixels at 72 Hz. NIDL’s tests show that the monoscopic contrast modulation is excellent and exceeds 50% over the face of the whole CRT, well above the performance of many other color monitors and approaches the values for grayscale monitors. The Cornerstone p1700 exceeds the IEC luminance specification in monoscopic and stereoscopic modes at 34 and 6.4 fL, respectively. The monitor exceeds the IEC stereo extinction ratio specification of 15:1 with the StereoGraphics CrystalEyes shutter glasses and achieves 21.0:1 at 60 Hz per eye. This is the highest extinction ratio value NIDL has measured for a color monitor. The stereo extinction ratio with the StereoGraphics Zscreen is 10.6:1. The color picture tube has a five year warranty. The price for the Cornerstone p1700 monitor is $1363.

Evaluation of the Cornerstone p1700 4 x 3 Aspect Ratio, 21-Inch Diagonal Color Monitor

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NIDL IEC Monitor Certification Report

The Cornerstone p1700 Color CRT Monitor

FINAL GRADES
Monoscopic Mode: A
Stereoscopic Mode: B

A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way.

NIDL certifies the 21 inch Cornerstone p1700 color monitor as being suitable for IEC workstations. NIDL rates this color monitor “A” in monoscopic and “B” in the stereoscopic mode for the Image Analyst and Cartographer applications. The Cornerstone p1700 is an excellent color monitor. It meets the stringent IEC 120 Hz (60 Hz per eye) stereo requirement. It can display up to 2048 x 1536 pixels at 72 Hz. NIDL’s tests show that the monoscopic contrast modulation is excellent and exceeds 50% over the face of the whole CRT, well above the performance of many other color monitors and approaches the values for grayscale monitors. The Cornerstone p1700 exceeds the IEC luminance specification in monoscopic and stereoscopic modes at 34 and 6.4 fL, respectively. The monitor exceeds the IEC stereo extinction ratio specification of 15:1 with the StereoGraphics CrystalEyes shutter glasses and achieves 21.0:1 at 60 Hz per eye. This is the highest extinction ratio value NIDL has measured for a color monitor. The stereo extinction ratio with the StereoGraphics Zscreen is 10.6:1. The color picture tube has a five year warranty. The price for the Cornerstone p1700 monitor is $1363.

The manufacturer states that, “Cornerstone is unique because we specialize in making Big Monitors and everything that goes into creating the ultimate large format professional display. Making a Big Monitor isn't so simple—by specializing we are able to produce an image quality difference you can see. Cornerstone has been sharpening image quality since 1986 and we're well known for manufacturing the ultimate professional displays. Cornerstone prides itself on the sharpest image in the industry—in fact typically 20% sharper than our leading competitors. We don't stop at just the monitor. We make BigMonitor Software™ to improve productivity and image quality. We make BigMonitor graphics cards to deliver performance tuned specifically to BigMonitor environments. And finally, we think you'll find our commitment to service our customers pretty Big as well. BigMonitor Software™ gives Cornerstone monitor users true colors and sharp images at every resolution, plus window management features that make switching between applications a snap. The reduced depth of the redesigned cabinet, its recessed connection panel and right-angle cables reduce its space requirement to that of a 19".” Their web site is http://www.bigmonitors.com/. The site also has a good section describing display technology and its technical terms.

A comparison of the Cornerstone with other color CRT monitors is shown in the following table.

NIDL Color Monitor Certification for IEC

Monitor Manufacturer	IEC Spec	Cornerstone	EIZO	Viewsonic		Mitsubishi		Hitachi	SONY		Siemens
Model		P1700	F980	PF815	P817	2040U	2020U	CM814	24W900	F500	SCM21 130
Certified*		Y	Y	N	Y	N	N	Y	Y	N	Y
Monoscopic		A	B	A	B	A	C	B	A	B-	B
Stereoscopic		B	B	C	B	C	C	B		C	B
Cm, Zone A	25%	57%	37%	55%	29%	54%	30%	35%	64%	43%	36%
Cm, Zone B	20%	52%	27%	47%	40%	42%	16%	30%	53%	37%	21%
Refresh per eye	60 Hz	60 Hz	60 Hz	55 Hz	60 Hz	55 Hz	55 Hz	60 Hz	46 Hz	56 Hz	60.5 Hz
Extinction ratio, panel	No spec	10.6	12.6	10.3	10.1	10.4	11.1	11.2	12.9	13.3	11.2
IR glasses	15.1	21.0	14.3	17.6		17.6					18.1
Price		$1363	$1790	$926	$1600	$1123		$1200	$2371	$1758	< $2800

* Certified by NIDL requires achieving a rating of “B” or above for stereoscopic and for monoscopic performance relative to the IEC Working Group specifications listed in the Evaluation Datasheet. This summary is a compilation of ratings for color monitors from previously NIDL IEC monitor reports. The ratings for the Cornerstone, Eizo, and the Viewsonic PF815 are new.

Evaluation Datasheet

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
Addressability	1024 x 1024 min.	1600 x 1200	Pass
Dynamic Range	24.7dB	25.4 dB	Pass
Luminance (Lmin)	0.1 fL ± 4% min.	0.10 fL	Pass
Luminance (Lmax)	30 fL ± 4%	34.8 fL	Pass
Uniformity (Lmax)	20% max.	11.5%	Pass
Halation	3.5% max.	4.17 ± 0.4%	Fail
Color Temp	6500 to 9300 K	9075	Pass
Reflectance	Not specified	5.0%	
Bit Depth	8-bit± 5 counts	8-bit	Pass
Step Response	No visible ringing	Clean	Pass
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 delta u'v'	0.0022 delta u'v'	Pass
Pixel aspect ratio	Square H = V± 6%	9.82 H x 9.86 V (mils) H = V- 0.4%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	19.7 ins.	Pass
Cm, Zone A, 7.6"	25% min.	57%	Pass
Cm, Zone A, 9.7"	25% min.	56%	Pass
Cm, Zone B	20% min.	52%	Pass
Pixel density	72 ppi min.	101 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.88	Pass
Straightness	0.5% max ± 0.05 mm	0.26%	Pass
Linearity	1.0% ± 0.05 mm max.	0.66%	Pass
Jitter	2 ± 2 mils max.	2.63 mils	Pass
Swim, Drift	5 ± 2 mils max.	3.04 mils	Pass
Warm-up time, Lmin to +/- 50%	30 ± 0.5 mins. Max	25 mins.	Pass
Warm-up time, Lmin to +/- 10%	60 ± 0.5 mins. Max	60 mins.	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute min.	Set to 85 Hz	Pass
STEREOSCOPIC		(S)	
Addressability	1024 x 1024 min.	1024 x 1024 (I)(z) 1024 x 1024 (I)(IR at 60 Hz) 1280 x 1024 (IR at 50 Hz)	Pass
Lmin	Not specified	0.1 fL	Pass
Lmax	6 fL min ± 4%	6.78 fL (z) 6.40 fL (IR at 50 Hz)	Pass Pass
Dynamic range	17.7 dB min	17.9 dB(z) 18.0 dB (IR at 50 Hz)	Pass Pass
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 Δ u'v'	0.010 delta u'v' (z) 0.018 delta u'v' (IR at 50 Hz)	Pass
Refresh rate	60 Hz per eye, min	60 Hz, per eye (z) 50 Hz, per eye (IR at 50 Hz)	Pass
Extinction Ratio	15:1 min with CrystalEyes	10.6:1 (ZScreen at 60Hz)	N/A
	15:1 min with CrystalEyes	21.0:1 (IR at 60Hz) 22.7:1 (IR at 50Hz)	Pass
AMBIENT LIGHTING			
Dynamic range = 21.4 dB (138:1)	N/A	3 fc	
Dynamic range = 17.7 dB (59:1)	N/A	10 fc	

(z) Denotes ZScreen and wired Eyewear. (IR) Denotes StereoGraphics CrystalEyes IR Eyewear
(S) Denotes Stereo can be accomplished at 120 Hz in 1280 x 1024 format (I) Denotes interlaced scanning

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics, hosts the NIDL.

The present study evaluates a production unit of the Cornerstone p1700 color CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091**,** Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC)*, August 25, 1999.

Two companion documents that describe how the measurements are made are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*

- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1 The Cornerstone p1700 Color CRT Monitor

Manufacturer's Specifications

Just how fast is the p1700 you ask, try 1600 x 1200 @ 100 Hz. Match that kind of speed with a maximum resolution of 2048 x 1536 and the p1700 is the perfect solution for demanding applications like CAD, document imaging or cutting edge graphic design. With its amazing 31-130 kHz horizontal scan frequency and an awesome pixel clock of 320 MHz, this 21-inch (20.0-inch viewable) monitor delivers the ultimate level of crystal clear performance.

According to Cornerstone, the specifications for the Cornerstone p1700 monitor are:

Specifications	Features
CRT Type	21" (20.0" diagonal viewable area) short depth
CRT Pitch	0.22mm horizontal dot pitch
CRT Phosphor	Short persistence
CRT Faceplate Glass	Direct Faceplate Coating, Anti-glare/Reflection/Static treatment
Preset/Maximum Display Area Size* (W x H)	15.6 x 11.6" or 15.9" x 12" (395 mm x 295 mm Default) or (406 mm x 305 mm)
Maximum Addressable Resolution Format (H x V pixels)	2048 x 1536 x 72Hz (maximum) 1600 x 1200 x 100Hz (optimum)
Compatibility	PC, Mac
Auto-Scan Range	H: 31 - 130 kHz V: 50 - 160 Hz
Video Pixel Clock Frequency	320 MHz
Fully Adjustable Color Balance	5000° - 9300° Continuously variable
Input Signal (Video)	0.70 Vp-p Analog
Input Signal (Sync)	Separate H/V, TTL level Composite H/V, TTL level Sync-on-green at 0.30 Vp-p
Connectors	Video: Dual 15-pin mini D-sub Power: 3-pin plug (Optional) USB Hub Module with 4 downstream and 1 upstream port
Signal Cable	15-pin mini D-sub, (right-angle cable included)
Power Requirements	100-120 VAC/200-240 VAC; 50/60 Hz
Power Consumption	130 W (typ)
Heat Dissipation	444 BTU/Hr
Power Cord	U.S. version cord with 3P plug
Compact Tilt/ Swivel Base	Integrated with monitor
Operating Conditions Temperature Humidity	 +41 to +104 degrees F. (+5 to +40 degrees C.) 10% to 80%
Dimensions (W x H x D)	19.5 x 19.3 x 18.8" (488 x 482 x 470 mm)
Net Weight	60.5 lbs. (27.5 kg)
Shipping Weight	70.4 lbs. (32 kg)
Regulatory Approvals	FCC Class A, TCO-95, UL, CSA, TUV-GS, DHHS, ISO 9241-3, CE, C-Tick, NORDIC
Power Management	VESA DPMS, Energy Star/Nutek,
On-Screen Controls (OSD)	Power, Degauss, Brightness, Contrast, Size, Centering, Moiré Reduction, Overall Geometry, Color Temperature, Input Connector Selector, OSD Position, OSD Color, Convergence, Language, Recall, Lockout Function
OSD Language Choices	English, German, Spanish, Italian and French
Warranty	5-Year Warranty (Upgrade Options Available)

I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Quantum Data 903 250 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimeter
- Graseby S370 Illuminance Meter
- Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and Spotseeker 4-Axis Positioner

Stereoscopic-mode measurements were made using the following commercially-available stereo products:

- StereoGraphics ZScreen 19-inch LCD shutter with passive polarized eyeglasses.
- StereoGraphics CrystalEyes IR Eyewear.

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic range and Screen Reflectance

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black dynamic range measured in 1600 x 1200 format is 25.4 dB in a dark room. It decreases to 21.4 dB (the absolute threshold for IEC is 22 dB) in 3 fc diffuse ambient illumination.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93}. Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are simultaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene icebox. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Data: Define dynamic range by: $DR=10\log(Lmax/Lmin)$

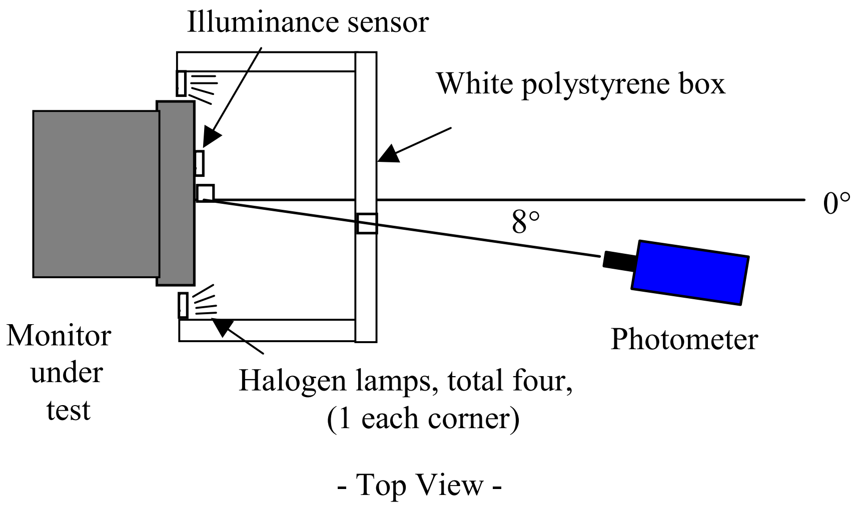


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	20.45 fc
Reflected Luminance	1.026 fL
Faceplate Reflectance	5.0 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range decreases from 25.4 in a dark room to 21.4 dB (the absolute threshold for IEC is 22 dB) in 3 fc diffuse ambient illumination.

Table II.1-2.Dynamic Range in Dark and Illuminated Rooms

Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.10.

Ambient Illumination	Displayed Addressable Format 1600 x 1200 Dynamic Range, dB
0 fc (Dark Room)	25.4 dB
1 fc	23.7 dB
2 fc	22.4 dB
3 fc	21.4 dB
4 fc	20.7 dB
5 fc	20.0 dB
6 fc	19.4 dB
7 fc	18.9 dB
8 fc	18.5 dB
9 fc	18.1 dB
10 fc	17.7 dB

II.2. Maximum Luminance (Lmax)

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.*

The highest luminance for Lmax was 34.8fL measured at screen center in 1600 x 1200 format.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was within range specified by IEC (6500K and 9300K).

Table II.2-1. Maximum Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at screen center.

Format	CCT	CIE x	CIE y	Luminance
1600 x 1200	9075K	0.280	0.309	34.8 fL

II.3. Luminance (Lmax) and Color Uniformity

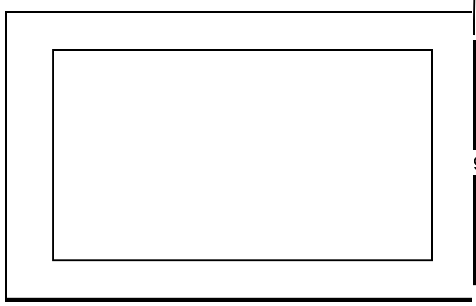
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 11.5% across the screen. Chromaticity variations were 0.0022 delta u'v' units or less.

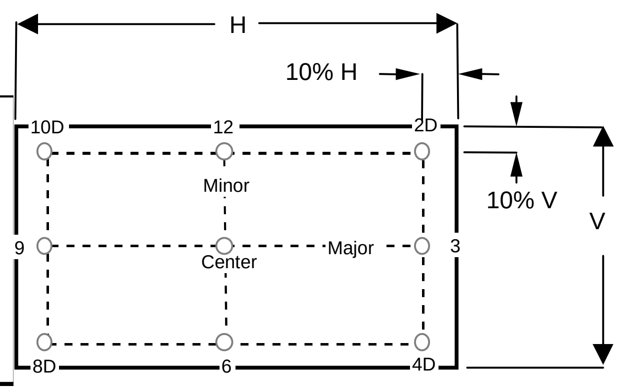
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.



Full Screen Flat Field test pattern.
Figure II.3-1



Nine screen test locations.
Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}. Measure the luminance and C.I.E. color coordinates at center screen.

Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of $\Delta u'v'$.

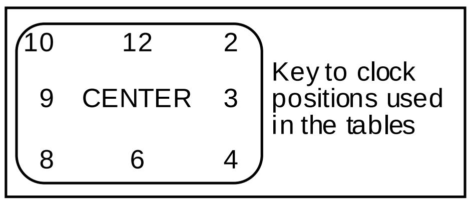
Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.Spatial Uniformity of Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at nine screen positions.

1600 x 1200

POSITION	CCT	CIE x	CIE y	L, fL
center	9075	0.280	0.309	34.8
2	8879	0.282	0.310	33.3
3	8912	0.282	0.309	31.9
4	8831	0.283	0.309	30.8
6	9145	0.280	0.307	31.9
8	9145	0.280	0.307	31.2
9	9267	0.279	0.306	31.8
10	9229	0.279	0.307	32.5
12	9229	0.279	0.307	33.9



1600 x 1200

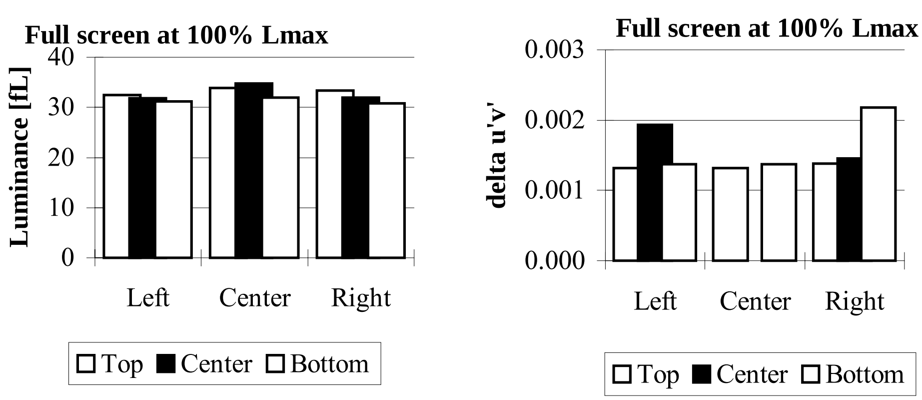


Fig.II.3-3. Spatial Uniformity of Luminance and Chromaticity. (Delta u'v' of 0.004 is just visible.)

II.4. Halation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

Halation was 4.17% +/- 0.4% n a small black patch surrounded by a large full white area.

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment:
- Photometer
- Video generator

Test Pattern:

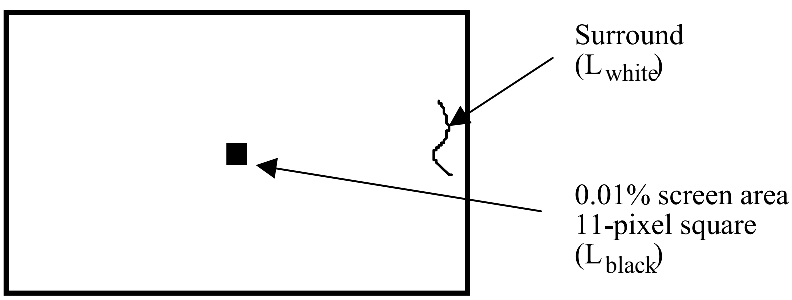


Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance (L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that

CRT beam is just on the verge of being cut off. These measurements should be made with a photometer that is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video-input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\% \text{ Halation} = L_{black} \; / \; (L_{white} - L_{black}) \times 100$$

Where, L_{black}= measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white}= measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max} .

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1600 x 1200 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	0.684 fL ± 4%	0.656 fL to 0.711 fL
Lwhite	16.4 fL ± 4%	15.74 fL to 17.06 fL
Halation	4.17% ± 0.4%	3.85% to 4.52%

II.5. Color Temperature

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

The CCT of the measured white point lies within the boundaries accepted by IEC.

Objective: Insure measured screen white of a color monitor has a correlated color temperature (CCT) between 6500K and 9300K.

Equipment: Colorimeter

Procedure: Command screen to Lmax. Measure u'v' chromaticity coordinates (CIE 1976).

Data: Coordinates of screen white should be within 0.01 Δu'v' of the corresponding CIE daylight, which is defined as follows: If the measured screen white has a CCT between 6500 and 9300 K, the corresponding daylight has the same CCT as the screen white. If the measured CCT is greater than 9300 K, the corresponding daylight is D93. If the measured CCT is less than 6500 K, the corresponding daylight is D65. The following equations were used to compute Δu'v' values listed in table II.5.1:

1. Compute the correlated color temperature (CCT) associated with (x,y) by the VESA/McCamy formula: CCT = 437 n^3 + 3601 n^2 + 6831 n + 5517, where n = (x-0.3320)/(0.1858 - y). [This is on p. 227 of the FPDM standard]

2. If CCT < 6500, replace CCT by 6500. If CCT > 9300, replace CCT by 9300.

4. Use formulas 5(3.3.4) and 6(3.3.4) in Wyszecki and Stiles (pp.145-146 second edition) to compute the point (xd,yd) associated with CCT.
   - First, define u = 1000/CCT.
   - If CCT < 7000, then xd = -4.6070 u^3 + 2.9678 u^2 + 0.09911 u +
   - 0.244063.
   - If CCT > 7000, then xd = -2.0064 u^3 + 1.9018 u^2 + 0.24748 u +
   - 0.237040.
   - In either case, yd = -3.000 xd^2 + 2.870 xd -0.275.

5. Convert (x,y) and (xd,yd) to u'v' coordinates:
   - (u',v') = (4x,9y)/(3 + 12y - 2x)
   - (u'd,v'd) = (4xd,9yd)/(3 + 12yd - 2xd)

6. Evaluate delta-u'v' between (u,v) and (ud,vd):
   - delta-u'v' = sqrt[(u' - u'd)^2 + (v' - v'd)^2].

7. If delta-u'v' is greater than 0.01, display fails the test. Otherwise it passes the test.

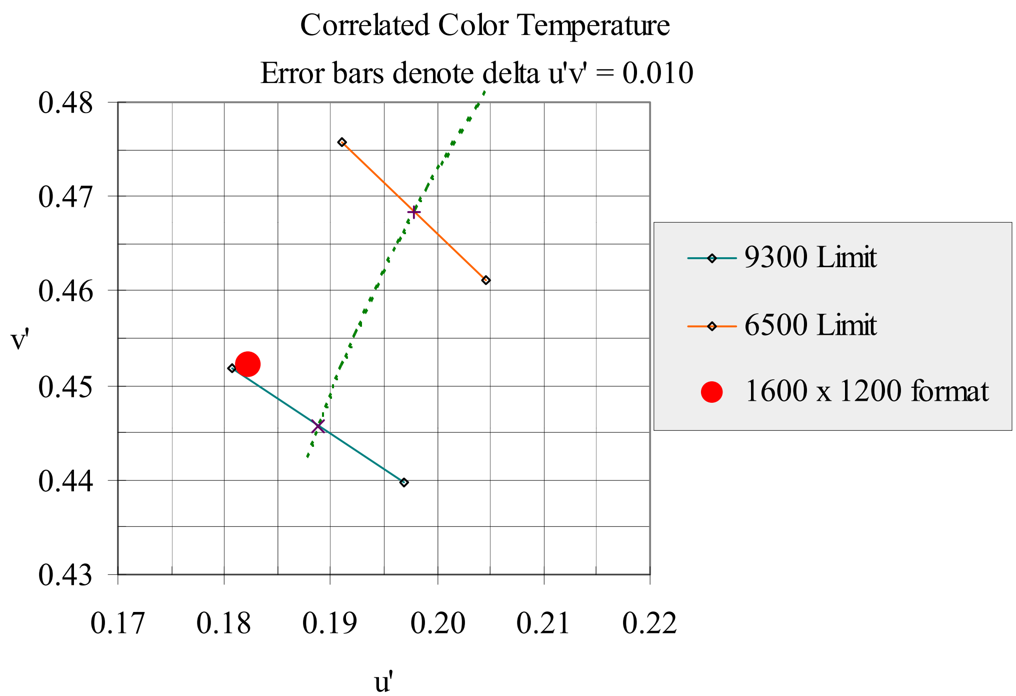


Figure II.5-1 *CCTs of measured white points are within the boundaries required by IEC.*

Table II.5-1 Δu'v' Distances between measured white points and CIE coordinate values from D_{65} to D_{93}.

	1600 x 1200
CIE x	0.280
CIE y	0.309
CIE u'	0.182
CIE v'	0.452
CCT	9075
delta u'v'	0.009

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. Neither black level clipping nor white level saturation was observed.

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

Test targets: Targets are n four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM model to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels. The NEMA/DICOM model was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve at center screen as a function of input counts. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.

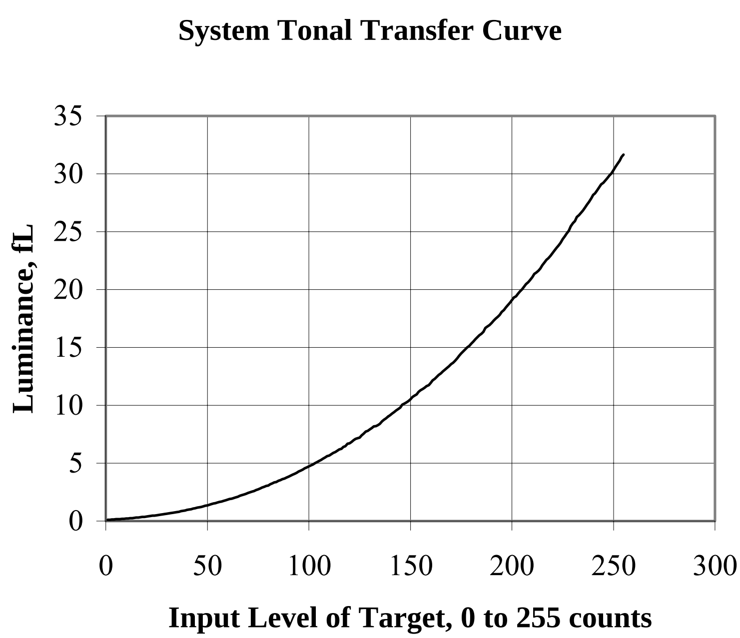


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

Table II.6-1. System Tonal Transfer at center screen as a function of input counts. Target levels 000 to 127.

Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.104	0.000	0
39	1	0.111	0.007	2
39	2	0.121	0.010	2
39	3	0.133	0.012	3
40	4	0.143	0.010	2
40	5	0.153	0.010	3
41	6	0.164	0.011	2
41	7	0.178	0.014	2
41	8	0.188	0.010	2
42	9	0.202	0.014	3
42	10	0.215	0.013	2
42	11	0.231	0.016	3
43	12	0.244	0.013	2
43	13	0.261	0.017	2
43	14	0.276	0.015	3
44	15	0.293	0.017	2
44	16	0.314	0.021	3
44	17	0.329	0.015	2
45	18	0.350	0.021	3
45	19	0.369	0.019	2
45	20	0.391	0.022	3
46	21	0.414	0.023	2
46	22	0.437	0.023	3
46	23	0.457	0.020	2
47	24	0.479	0.022	2
47	25	0.506	0.027	3
48	26	0.532	0.026	3
48	27	0.557	0.025	2
48	28	0.581	0.024	2
49	29	0.612	0.031	3
49	30	0.646	0.034	3
49	31	0.667	0.021	2
50	32	0.691	0.024	2
50	33	0.724	0.033	2
50	34	0.752	0.028	3
51	35	0.786	0.034	2
51	36	0.812	0.026	2
51	37	0.852	0.040	3
52	38	0.884	0.032	2
52	39	0.921	0.037	3
52	40	0.958	0.037	2
53	41	0.989	0.031	2
53	42	1.033	0.044	3
53	43	1.068	0.035	2
54	44	1.106	0.038	3
54	45	1.148	0.042	2
55	46	1.191	0.043	3
55	47	1.227	0.036	2
55	48	1.268	0.041	2
56	49	1.314	0.046	2
56	50	1.367	0.053	3
56	51	1.415	0.048	3
57	52	1.457	0.042	2
57	53	1.512	0.055	2
57	54	1.552	0.040	2
58	55	1.602	0.050	3
58	56	1.646	0.044	2
58	57	1.698	0.052	2
59	58	1.744	0.046	2
59	59	1.786	0.042	2
59	60	1.848	0.062	2
60	61	1.896	0.048	2
60	62	1.947	0.051	3
60	63	1.998	0.051	2

Background	Target	L, fL	Diff, fL	Diff, JND
61	64	2.031	0.033	1
61	65	2.089	0.058	2
62	66	2.172	0.083	3
62	67	2.236	0.064	3
62	68	2.286	0.050	2
63	69	2.342	0.056	2
63	70	2.427	0.085	2
63	71	2.483	0.056	2
64	72	2.535	0.052	2
64	73	2.602	0.067	2
64	74	2.689	0.087	3
65	75	2.742	0.053	2
65	76	2.804	0.062	2
65	77	2.903	0.099	3
66	78	2.958	0.055	2
66	79	3.026	0.068	2
66	80	3.072	0.046	1
67	81	3.164	0.092	3
67	82	3.246	0.082	2
67	83	3.336	0.090	2
68	84	3.380	0.044	2
68	85	3.473	0.093	2
69	86	3.549	0.076	2
69	87	3.618	0.069	2
69	88	3.687	0.069	2
70	89	3.768	0.081	2
70	90	3.842	0.074	1
70	91	3.928	0.086	3
71	92	3.993	0.065	1
71	93	4.077	0.084	2
71	94	4.180	0.103	3
72	95	4.294	0.114	2
72	96	4.352	0.058	1
72	97	4.436	0.084	2
73	98	4.556	0.120	3
73	99	4.645	0.089	2
73	100	4.711	0.066	1
74	101	4.802	0.091	2
74	102	4.903	0.101	2
74	103	5.005	0.102	2
75	104	5.078	0.073	2
75	105	5.183	0.105	2
76	106	5.272	0.089	2
76	107	5.391	0.119	2
76	108	5.502	0.111	2
77	109	5.595	0.093	2
77	110	5.668	0.073	1
77	111	5.772	0.104	2
78	112	5.887	0.115	2
78	113	5.979	0.092	1
78	114	6.074	0.095	2
79	115	6.192	0.118	2
79	116	6.232	0.040	1
79	117	6.398	0.166	3
80	118	6.471	0.073	1
80	119	6.672	0.201	3
80	120	6.711	0.039	1
81	121	6.832	0.121	2
81	122	6.976	0.144	2
81	123	7.104	0.128	2
82	124	7.157	0.053	1
82	125	7.223	0.066	1
83	126	7.399	0.176	2
83	127	7.542	0.143	2

Table II.6-2. System Tonal Transfer at center screen as a function of input counts 128 to 255.

Back ground	Target	L, fL	Diff, fL	Diff, JND	Back ground	Target	L, fL	Diff, fL	Diff, JND
83	128	7.728	0.186	3	106	192	17.48	0.17	2
84	129	7.787	0.059	1	106	193	17.65	0.17	1
84	130	7.918	0.131	2	106	194	17.83	0.18	1
84	131	8.038	0.120	1	107	195	18.08	0.25	2
85	132	8.175	0.137	2	107	196	18.23	0.15	1
85	133	8.204	0.029	1	107	197	18.45	0.22	1
85	134	8.292	0.088	1	108	198	18.66	0.21	2
86	135	8.402	0.110	1	108	199	18.86	0.20	1
86	136	8.607	0.205	3	108	200	19.10	0.24	2
86	137	8.765	0.158	2	109	201	19.32	0.22	1
87	138	8.858	0.093	1	109	202	19.41	0.09	1
87	139	9.024	0.166	2	109	203	19.65	0.24	1
87	140	9.141	0.117	2	110	204	19.84	0.19	2
88	141	9.293	0.152	2	110	205	20.03	0.19	1
88	142	9.413	0.120	1	111	206	20.24	0.21	1
88	143	9.561	0.148	2	111	207	20.46	0.22	2
89	144	9.678	0.117	1	111	208	20.63	0.17	1
89	145	9.801	0.123	2	112	209	20.82	0.19	1
90	146	10.050	0.249	3	112	210	21.08	0.26	1
90	147	10.130	0.080	1	112	211	21.34	0.26	2
90	148	10.240	0.110	1	113	212	21.46	0.12	1
91	149	10.370	0.130	1	113	213	21.64	0.18	1
91	150	10.530	0.160	2	113	214	21.81	0.17	1
91	151	10.710	0.180	2	114	215	22.11	0.30	2
92	152	10.820	0.110	1	114	216	22.35	0.24	1
92	153	10.950	0.130	2	114	217	22.57	0.22	1
92	154	11.170	0.220	2	115	218	22.72	0.15	1
93	155	11.290	0.120	1	115	219	22.94	0.22	1
93	156	11.410	0.120	2	115	220	23.15	0.21	2
93	157	11.530	0.120	1	116	221	23.37	0.22	1
94	158	11.670	0.140	1	116	222	23.61	0.24	1
94	159	11.740	0.070	1	116	223	23.82	0.21	1
94	160	11.940	0.200	2	117	224	24.03	0.21	1
95	161	12.150	0.210	2	117	225	24.37	0.34	2
95	162	12.290	0.140	1	118	226	24.59	0.22	2
95	163	12.470	0.180	2	118	227	24.84	0.25	1
96	164	12.620	0.150	2	118	228	25.08	0.24	1
96	165	12.760	0.140	1	119	229	25.48	0.40	2
97	166	12.940	0.180	2	119	230	25.74	0.26	2
97	167	13.080	0.140	1	119	231	25.92	0.18	0
97	168	13.220	0.140	1	120	232	26.28	0.36	2
98	169	13.380	0.160	2	120	233	26.45	0.17	1
98	170	13.560	0.180	1	120	234	26.63	0.18	1
98	171	13.680	0.120	1	121	235	26.82	0.19	1
99	172	13.840	0.160	2	121	236	27.09	0.27	1
99	173	14.070	0.230	2	121	237	27.34	0.25	2
99	174	14.270	0.200	1	122	238	27.57	0.23	1
100	175	14.480	0.210	2	122	239	27.86	0.29	1
100	176	14.670	0.190	2	122	240	28.17	0.31	2
100	177	14.840	0.170	1	123	241	28.31	0.14	0
101	178	15.010	0.170	2	123	242	28.60	0.29	2
101	179	15.140	0.130	1	123	243	28.84	0.24	1
101	180	15.320	0.180	1	124	244	29.08	0.24	1
102	181	15.510	0.190	2	124	245	29.24	0.16	1
102	182	15.730	0.220	1	125	246	29.41	0.17	0
102	183	15.880	0.150	2	125	247	29.62	0.21	1
103	184	16.040	0.160	1	125	248	29.87	0.25	1
103	185	16.180	0.140	1	126	249	30.03	0.16	1
104	186	16.340	0.160	1	126	250	30.33	0.30	1
104	187	16.680	0.340	3	126	251	30.62	0.29	2
104	188	16.810	0.130	1	127	252	30.85	0.23	1
105	189	16.940	0.130	1	127	253	31.14	0.29	1
105	190	17.120	0.180	1	127	254	31.47	0.33	1
105	191	17.310	0.190	1	128	255	31.67	0.20	1

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

No video artifacts were observed.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern

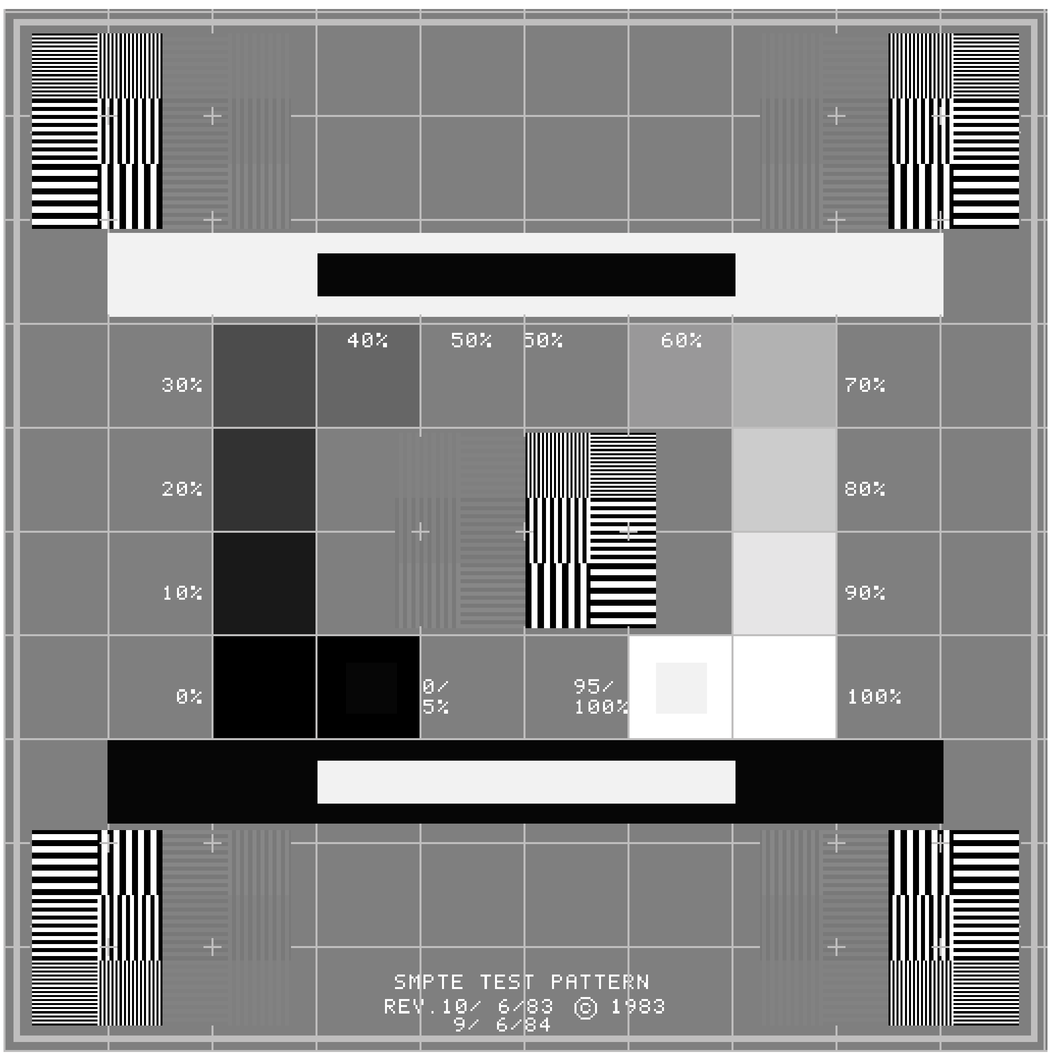


Figure II.8-1. SMPTE Test Pattern.

Data: Define passes by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." None of these artifacts was observed in the Cornerstone p1700 monitor, signifying good electrical performance of the video circuits.

II.9. Addressability

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all addressed pixels for the following tested formats (HxV): 1600 x 1200 x 85 Hz, and 1024 x 1024 x 120 Hz.

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H & V grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 85 Hz refresh rate which exceeds the 72 Hz minimum required by IEC for monoscopic mode and 120 Hz for stereoscopic mode, the minimum required by IEC. All perimeter lines were confirmed to be visible with no irregular jaggies on diagonals.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

Table II.9-1 Addressabilities Tested

Monoscopic Mode	Stereo Mode
1600 x 1200 x 85 Hz	1024 x 1024 x 120 Hz

II.10. Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is within 0.43%.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

	Monoscopic Mode
Addressability (H x V)	**1600 x 1200**
H x V Image Size (inches) H x V Pixel Spacing (mils) H x V Pixel Aspect Ratio	15.714 x 11.836 9.82 x 9.86 mils H = V - 0.43%

II.11. Screen Size (Viewable Active Image)

Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

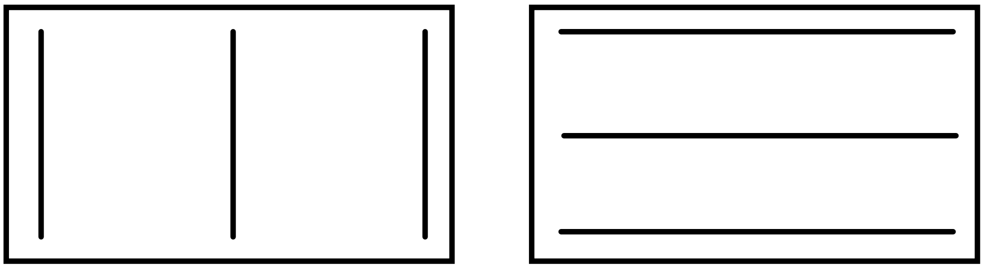
Image size for 1600 x 1200 format was 19.673 inches in diagonal.

Objective: Measure beam position on the CRT display to quantify width and height of active image size visible by the user (excludes any over scanned portion of an image).

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be

positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square-root of the sum of the squares of the width and height.

Table II.11-1. Image Size

	Monoscopic Modes
Addressability (H x V)	1600 x 1200
H x V Image Size (inches) Diagonal Image Size (inches)	15.714 x 11.836 19.673

II.12. Contrast Modulation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 57% in Zone A of diameter 7.6 inches, and 56% for Zone A diameter of 9.73 inches (40% of image area). Cm exceeded 52% in Zone B. Moiré cancellation circuitry was turned OFF for this measurement.

Objective: Quantify contrast modulation as a function of screen position.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

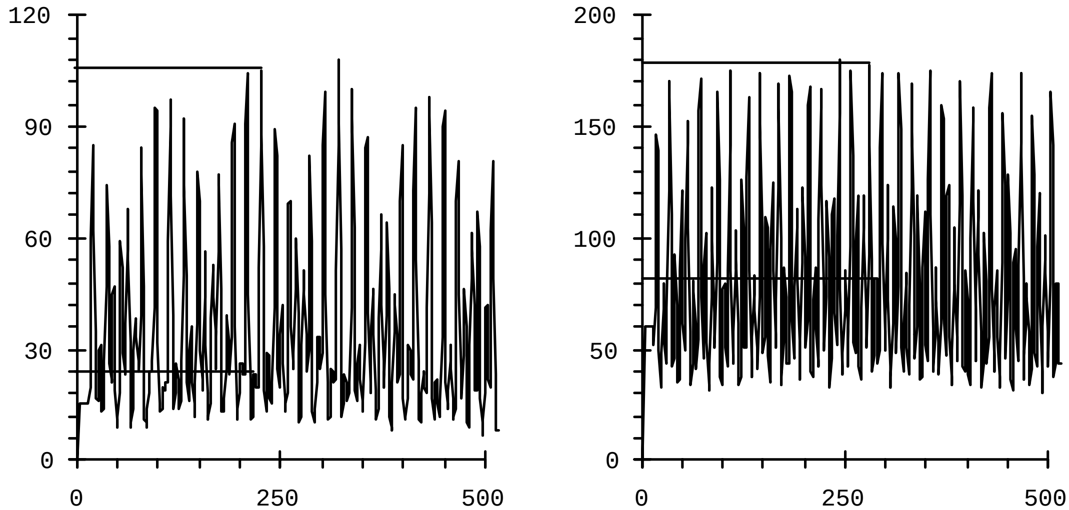
Procedure: The maximum video modulation frequency for each format (1280 x 1024, 1620 x 1024, 1920 x 1200) was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax.

Zone A is defined as a 24 degree subtended circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 56% in Zone A, and is equal to or greater than 52% in Zone B.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

The sample contrast modulations shown in Figure II.12-1 for two different color CRTs are not fully realized because of the presence of moiré caused by aliasing between the image and the shadow mask. Because contrast modulation values are calculated for the maximum peak and minimum valley luminance levels as indicated in the sample data shown, they do not include the degrading effects of aliasing.



Monitor A
0.28mm dot pitch

Monitor B
0.26mm dot pitch

Figure II.12-1. *Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for monitors exhibiting moiré due to aliasing.*

Table II.12-1. Contrast Modulation

Corrected for lens flare and Zone Interpolation

Moiré Cancellation OFF

Zone A = 7.6-inch diameter circle for 24-degree subtended circle at 18-inches viewing distance

	Left			Minor		Right
	H-grille V-grille	H-grille V-grille	H-grille V-grille	H-grille V-grille	H-grille V-grille
Top	75% 53%		74% 64%		83% 57%
		77% 58%	75% 63%	80% 60%	
Major	86% 52%	82% 57%	78% 61%	85% 61%	92% 60%
		79% 59%	68% 63%	79% 58%	
Bottom	79% 56%		62% 64%		80% 54%

Zone A = 9.73-inch diameter circle for 40% area

	Left		Minor		Right
	H-grille V-grille	H-grille V-grille	H-grille V-grille	H-grille V-grille	H-grille V-grille
Top	75% 53%		74% 64%		83% 57%
		76% 57%	75% 64%	81% 59%	
Major	86% 52%	83% 56%	78% 61%	86% 60%	92% 60%
		79% 59%	65% 63%	79% 58%	
Bottom	79% 56%		62% 64%		80% 54%

II.13. Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was 101 ppi as tested for the 1600 x 1200-line addressable format.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Mode
H x V Addressability, Pixels	1600 x 1200
H x V Image Size, Inches H x V Pixel Density, ppi	15.714 x 11.836 102 x 101 ppi

II.14. Moiré

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

Phosphor-to-pixel spacing ratio is 0.88 at screen center for the 1600 x 1200 format. Moiré compensation circuitry was not evaluated.

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

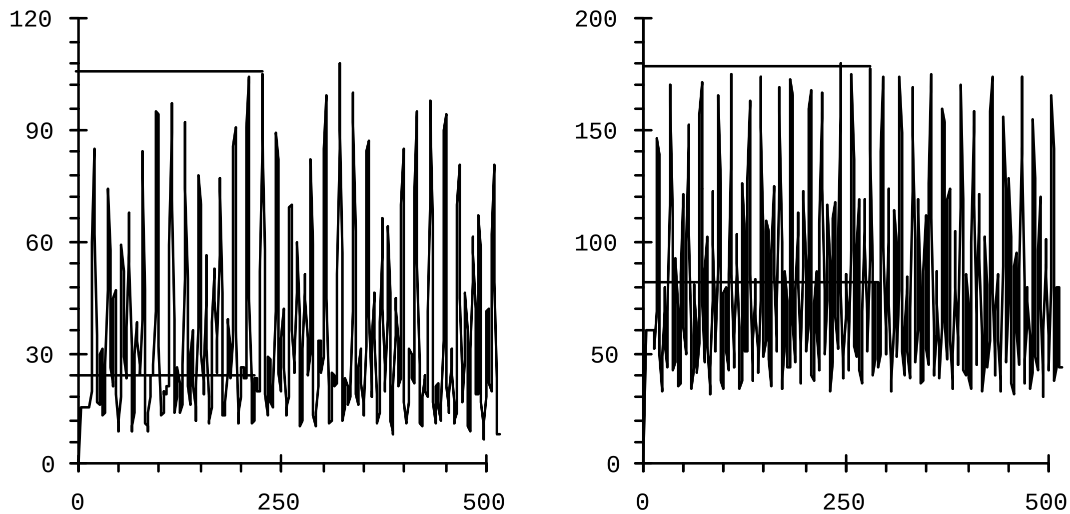
Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

Data: Define value of phosphor: pixel spacing. Value <1 passes, but <0.6 preferred.

Table II.14-1. Phosphor-to-Pixel-Spacing Ratios

	Monoscopic Mode
Addressability	1600 x 1200
Phosphor Pitch, horizontal	0.22mm
Pixel Spacing, horizontal	9.82 mils (0.24943 mm)
Phosphor-to-Pixel-Spacing	0.88

Discussion: Moiré occurs when the phosphor pitch is too large in comparison to the pixel size. Studies have shown that a phosphor pitch of about 0.6 pixels or less is required for adequate visibility of image information without interference from the phosphor structure.



Monitor A
0.28mm dot pitch

Monitor B
0.26mm dot pitch

Figure II.14-1. *Contrast modulation for sample luminance profiles (1pixel at level 50, 1 pixel at level 0) for monitors exhibiting moiré due to aliasing.*

In Figure II.14-1, Monitor A phosphor pitch is 0.90 pixels as compared with 0.84 pixels in Monitor B. Moiré is more visible in Monitor A, appearing as long stripes where contrast modulation has been degraded. In Monitor B, moiré is less visible, appearing as "fish-scales" where contrast modulation has been reduced. Even though the Monitor A exhibits a greater loss of contrast modulation from the presence of moiré on 1-on/1-off vertical grille patterns, there is little or no visual impact when aerial photographic images are displayed. NIDL experts in human vision and psychophysics were unable to discern presence of moiré on either monitor when grayscale imagery was displayed.

II.15. Straightness

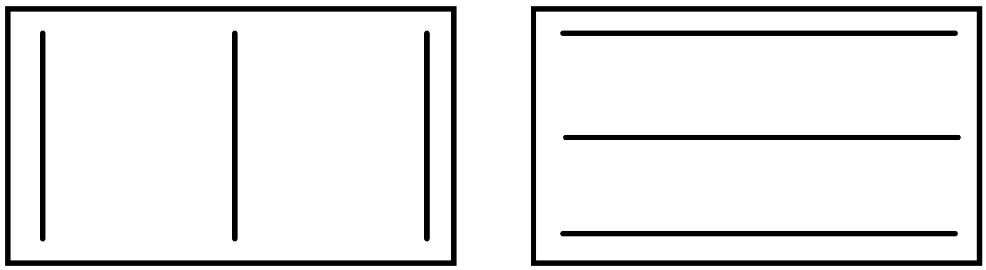
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.26% of the image width or height.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.15-1 Three-line grille test patterns.

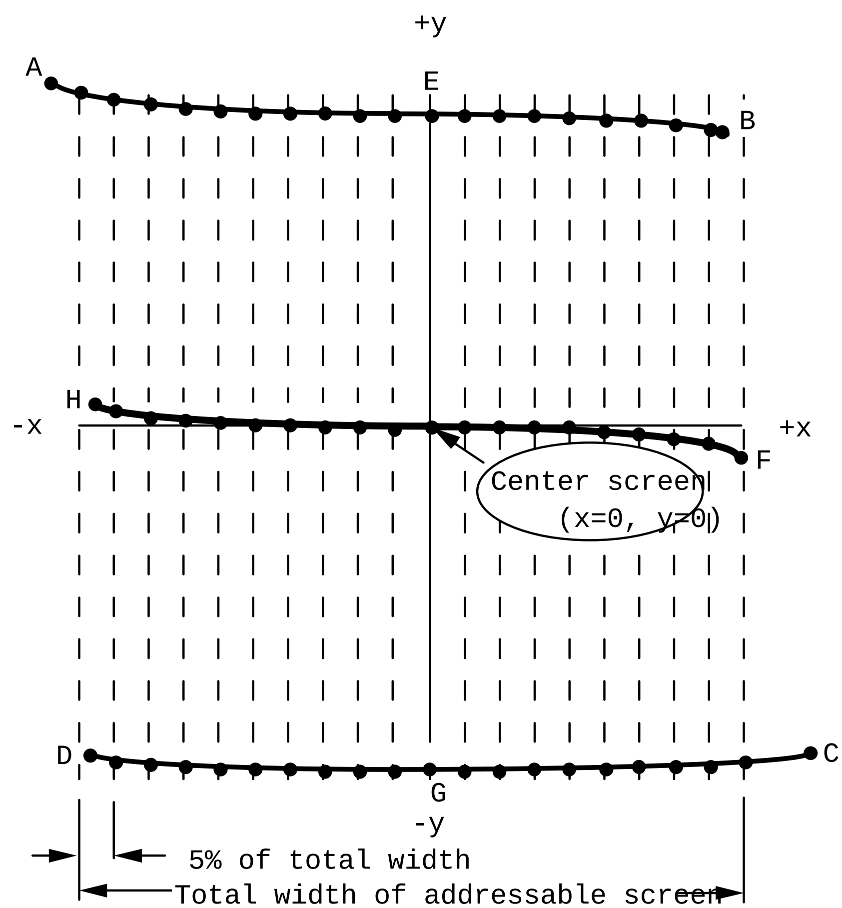


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

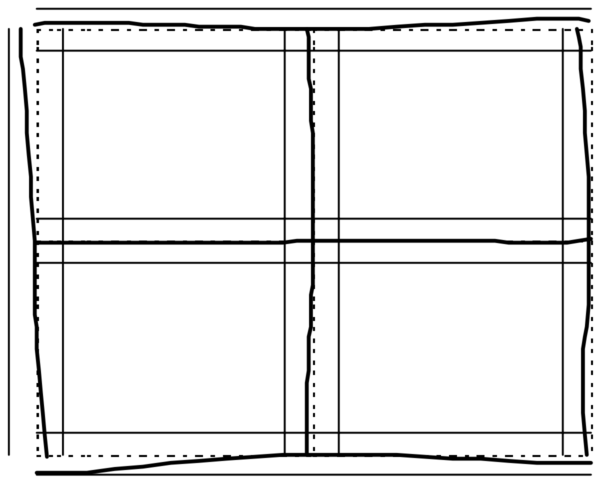
Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x,y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

Table II.15-1. Straightness

Tabulated x,y positions at 5% addressable screen increments along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-7855	5889	-7786	-5975	-7818	-6	-14	5876	-7855	5889	7874	5898
-7200	5893	-7200	-5975	-7200	-4	-12	5400	-7855	5400	7880	5400
-6400	5895	-6400	-5973	-6400	-4	-8	4800	-7850	4800	7885	4800
-5600	5894	-5600	-5966	-5600	-5	-6	4200	-7846	4200	7889	4200
-4800	5890	-4800	-5957	-4800	-5	-4	3600	-7842	3600	7892	3600
-4000	5887	-4000	-5949	-4000	-5	-1	3000	-7838	3000	7896	3000
-3200	5884	-3200	-5943	-3200	-5	0	2400	-7835	2400	7900	2400
-2400	5881	-2400	-5935	-2400	-4	1	1800	-7831	1800	7903	1800
-1600	5879	-1600	-5930	-1600	-2	1	1200	-7827	1200	7906	1200
-800	5876	-800	-5926	-800	-2	1	600	-7823	600	7907	600
0	5876	0	-5923	0	0	0	0	-7818	0	7908	0
800	5876	800	-5923	800	1	0	-600	-7816	-600	7908	-600
1600	5878	1600	-5925	1600	1	-2	-1200	-7815	-1200	7907	-1200
2400	5881	2400	-5927	2400	1	-4	-1800	-7815	-1800	7905	-1800
3200	5886	3200	-5932	3200	1	-7	-2400	-7812	-2400	7899	-2400
4000	5891	4000	-5934	4000	1	-11	-3000	-7809	-3000	7891	-3000
4800	5896	4800	-5938	4800	0	-13	-3600	-7805	-3600	7887	-3600
5600	5900	5600	-5940	5600	-2	-15	-4200	-7799	-4200	7886	-4200
6400	5904	6400	-5945	6400	-5	-16	-4800	-7795	-4800	7887	-4800
7200	5904	7200	-5948	7200	-5	-16	-5400	-7788	-5400	7892	-5400
7874	5898	7897	-5949	7912	9	-16	-5922	-7786	-5975	7897	-5949



1600 x 1200

Figure II.15-3 Waviness of Cornerstone p1700 color monitor in 1600 x 1200 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

Vertical refresh rate for 1600 x 1200 format was set to 85 Hz. Vertical refresh rate for the 1024 x 1024 stereo format was 120 Hz.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	**Stereo Mode**
Addressability	1600 x 1200	1024 x 1024
Vertical Scan Horizontal Scan	85.0 Hz 106.25 kHz	120 Hz 130.5 kHz

II.17. Extinction Ratio (StereoGraphics ZScreen)

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio averaged 10.6 to 1 (10.7 left, 10.4 right) at screen center using StereoGraphics Z-Screen 19-inch LCD shutter operating at 60 Hz per eye and viewed through passive polarized eyeglasses. Luminance of white with Z-screen varied by up to 10.3% across the screen, and chromaticity variations of white were less than 0.010 delta u'v' units.

Objective: Measure stereo extinction ratio

Equipment: Two “stereo” pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made at nine points across the screen using a commercially-available StereoGraphics ZScreen 19-inch LCD shutter with passive polarized eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and 35 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~
trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.

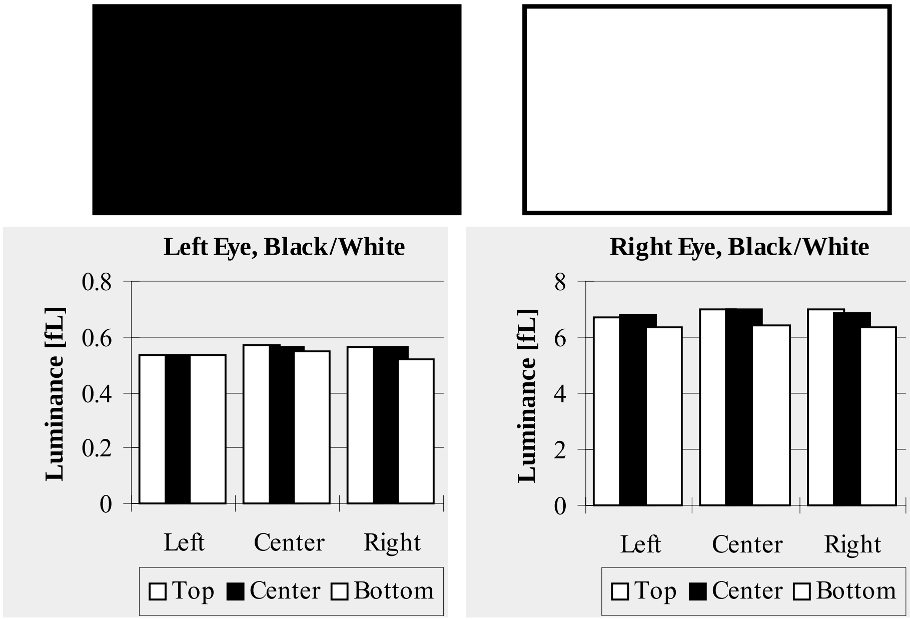


Fig.II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

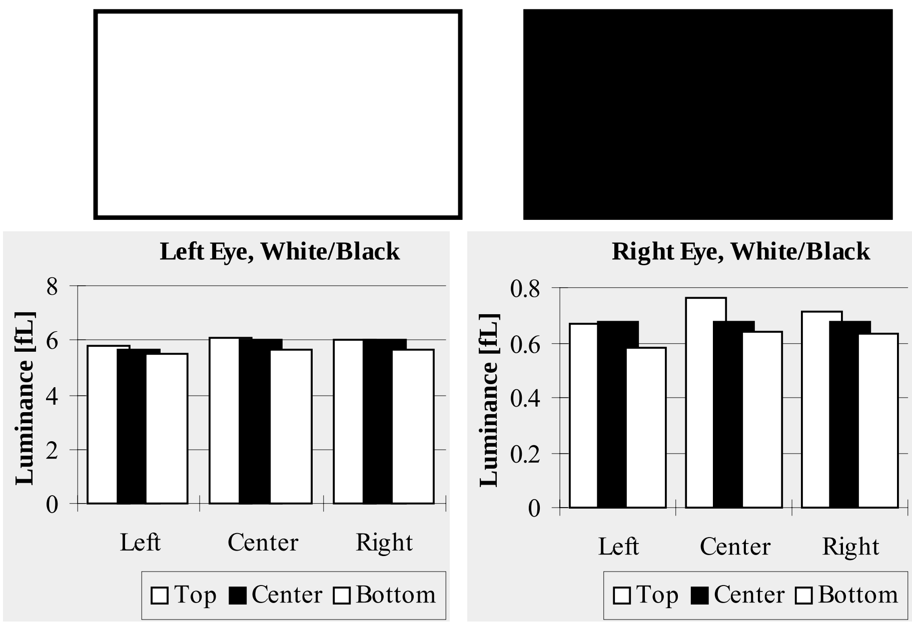


Fig.II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

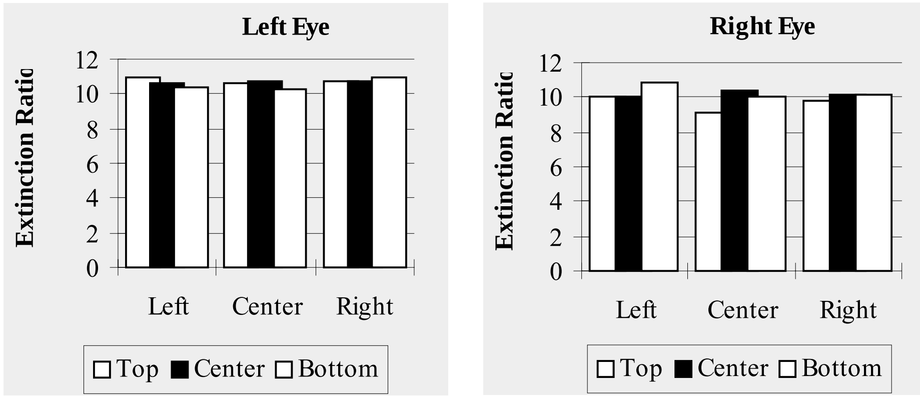


Fig.II.17-3. Spatial Uniformity of extinction ratio in stereo mode.

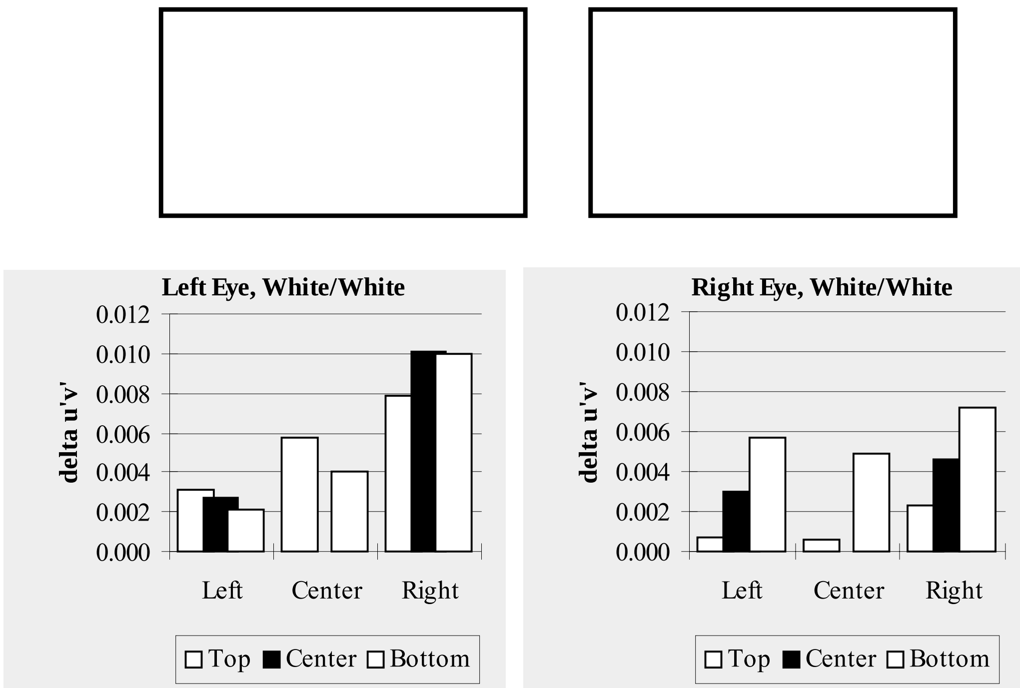


Fig.II.17-4 Spatial uniformity of chromaticity of white in stereo mode.

II.17.1. Extinction Ratio (StereoGraphics IR Eyewear)

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio averaged 21.0 to 1 (21.3 left, 20.7 right) at screen center when tested in 1024 x 1024 x 120 Hz (60 Hz per eye) mode. Stereo extinction ratio increased slightly to average 22.7 to 1 (22.0 left, 23.5 right) at screen center when tested in 1280 x 1024 x 100 Hz (50 Hz per eye) mode. At 50 Hz, luminance of white varied by up to 33.1% across the screen. Chromaticity variations of white were less than 0.018 delta u'v' units.

Objective: Measure stereo extinction ratio

Equipment: Two “stereo” pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using a commercially available StereoGraphics CrystalEyes 3 Stereoscopic Visualization Eyewear and ENT Emitter.

Procedure: Calibrate monitor to 0.1 fL Lmin and 6.0 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~
trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.

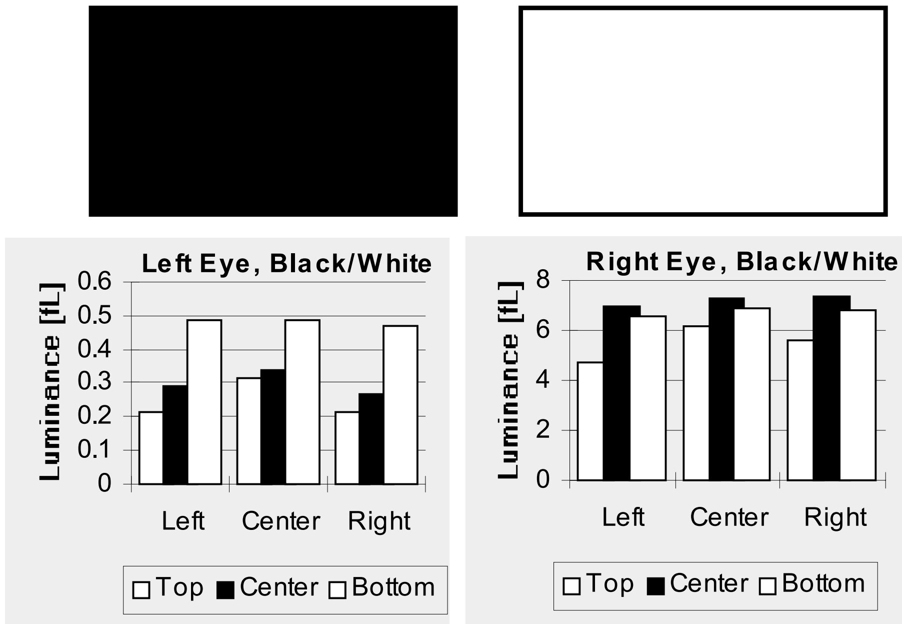


Fig.II.17-1.1 Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

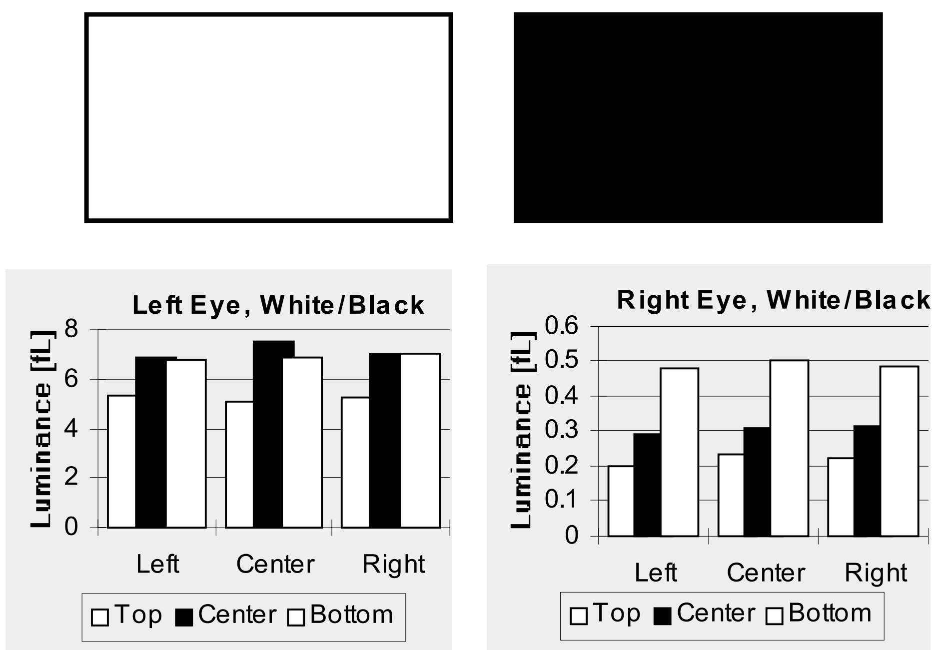


Fig.II.17-1.2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

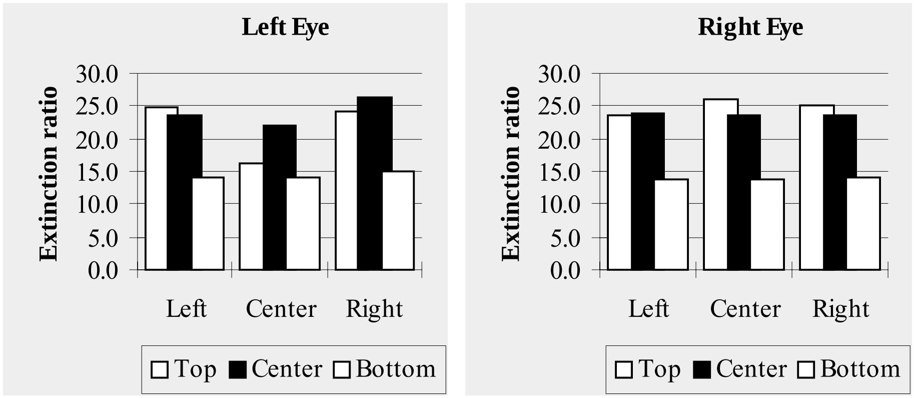


Fig.II.17-1.3. Spatial Uniformity of extinction ratio in stereo mode.

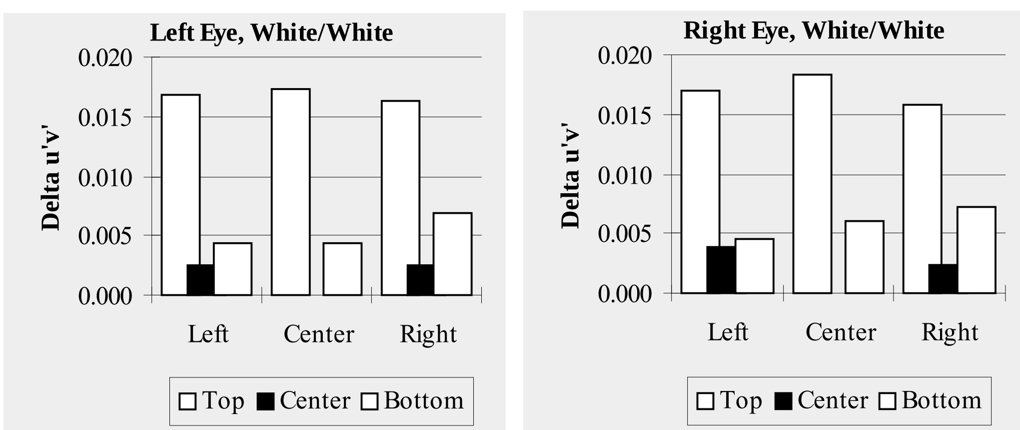


Fig.II.17-1.4 Spatial uniformity of chromaticity of white in stereo mode.

II.18. Linearity

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the scan was 0.66% of full screen.

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.

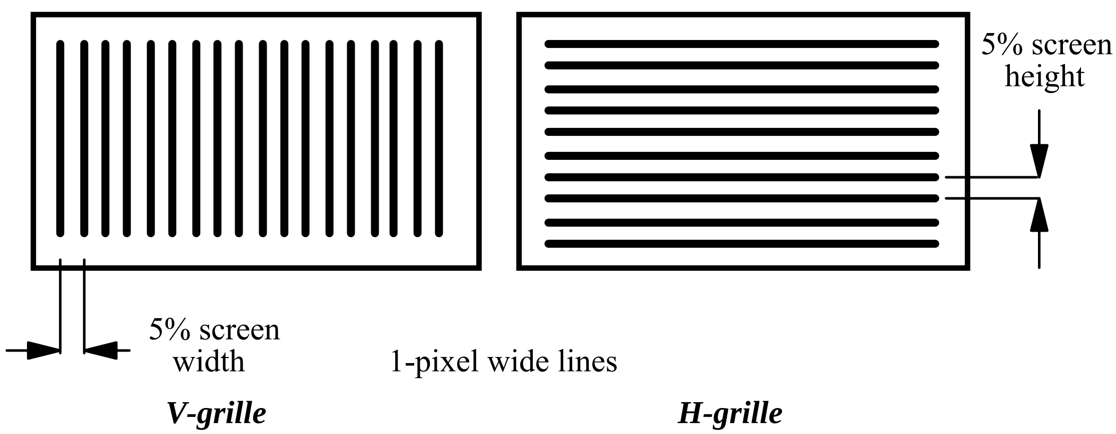


Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x,y-translation stage to measure screen x,y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

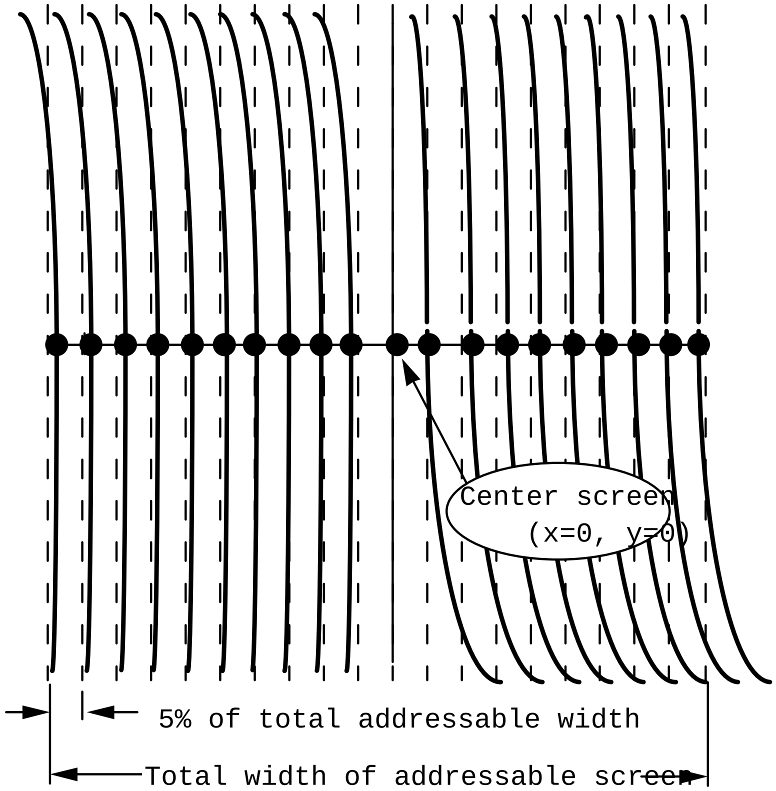


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

Data: Tabulate x, y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impact the absolute position of each pixel on the screen and are, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figures II.18-3 and II.18-4.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities

Format	Left Side	Right Side	Top	Bottom
1600 x 1200	0.11%	0.62%	0.35%	0.66%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	Right Side	Top	Bottom
-7735	7814	5786	-5823
-6971	7054	5206	-5238
-6201	6274	4626	-4650
-5427	5485	4045	-4062
-4653	4695	3464	-3476
-3878	3903	2884	-2895
-3104	3116	2304	-2312
-2327	2329	1725	-1730
-1551	1550	1151	-1150
-773	773	575	-574
0	0	0	0

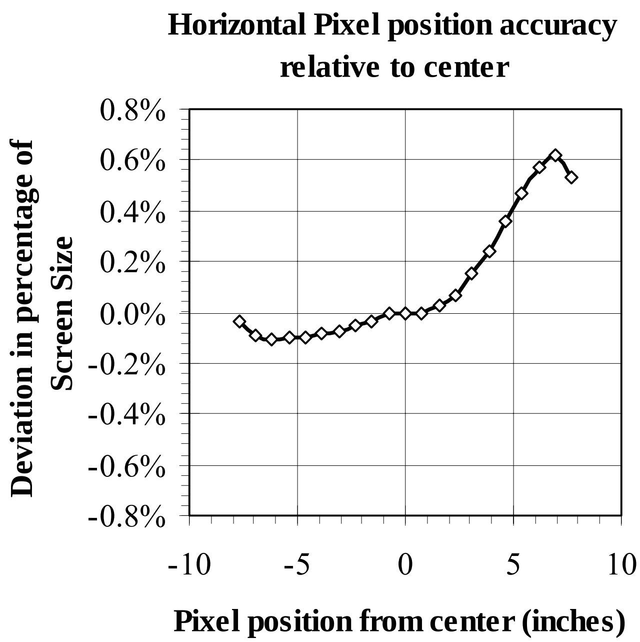


Fig. II.18-3 Horizontal linearity characteristic.

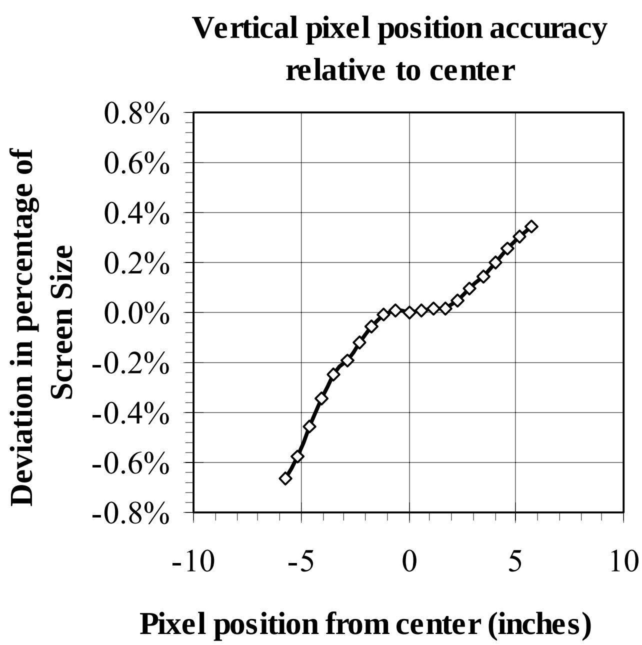


Fig. II.18-4 Vertical linearity characteristic

II.19. Jitter/Swim/Drift

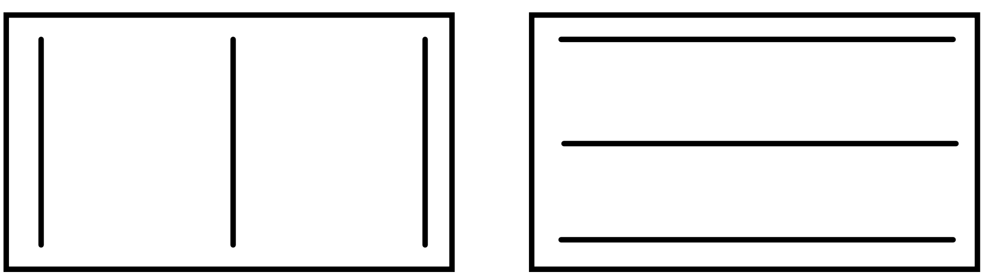
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift was 2.63 mils and 3.04 mils, respectively.

Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depends upon the amplitude and frequency of the motions, which can be caused by imprecise control electronics or external magnetic fields.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.
Figure II.19-1

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

Moiré Compensation OFF

1600 x 1200 x 72hz

		H-lines	V-lines	
10D corner	Max Motions			
	Jitter	2.06	2.84	
	Swim	2.08	3.16	
	Drift	2.17	3.28	
Black Tape	Max Motions			
	Jitter	0.246	0.213	
	Swim	0.253	0.235	
	Drift	0.273	0.243	
Less Tape Motion				Maximums
	Jitter	1.81	2.63	2.63
	Swim	1.83	2.93	2.93
	Drift	1.90	3.04	3.04

II.20. Warm-up Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

A 60 minute warm-up was necessary for luminance stability of Lmin = 0.101 fL + 10%.

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1600 x 1200 format in graphical form. The luminance remains very stable after 21 minutes.

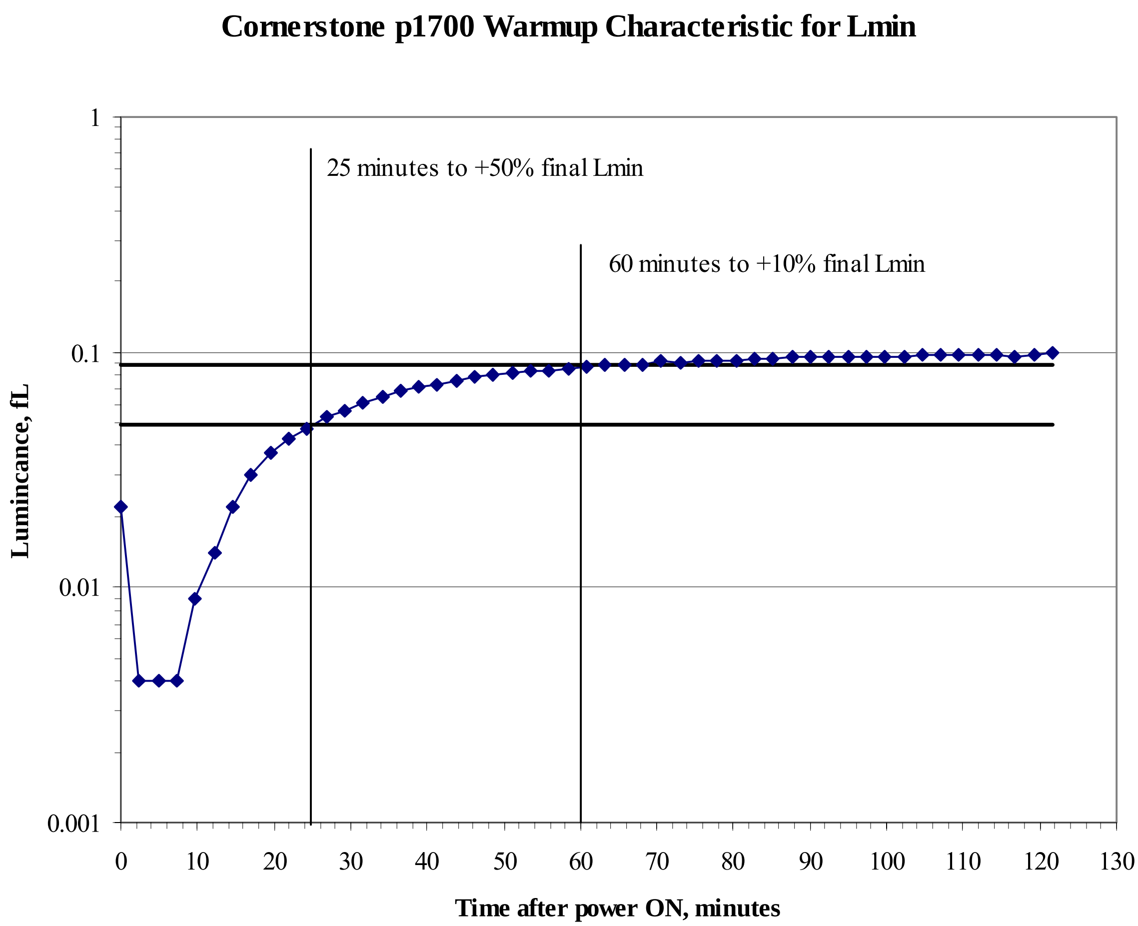


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).